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From the Editors

There is a theme, vaguely evident, running through most of the papers in this issue of *The Victorian Naturalist*, one of observing fauna in an environment that is in some respects new. Jayawardana's study focuses on macroinvertebrate species adapting to new habitats created by the presence of willow in stream courses; Christie has observed an aggregation of Port Jackson sharks in Port Phillip Bay; and Selkirk looks at the range of avian species to be found in the grounds of Monash University. Each of these papers highlights change in a range of physical environments, and underline the need for regular monitoring of all aspects of the natural world.

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Back cover: Australian Magpie *Cracticus tibicen*. Photo by Virgil Hubregtse. See p. 119

A novel littoral habitat from a riparian invader: implications on stream secondary production and riparian management

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Abstract

Understanding the functional role of invasive species is important for better management of ecosystems. Exotic willows (*Salix* spp.) are widespread riparian trees of temperate Australia and New Zealand. Despite being classed as weeds of national significance, little is known of their effects on ecosystem function. Extensive growth of complex willow root mats in streams they infest has created a novel littoral habitat. Spatial and temporal changes of macroinvertebrates in willow root mats and bare bank habitats were examined in three central Victorian rivers to gain an understanding of their effects on this faunal group. Macroinvertebrate richness, abundance, biomass and diversity were significantly higher ($p < 0.05$) in willow root habitats compared to open bank habitats. This suggests willow root mats have created a new niche for macroinvertebrate communities in willow-infested streams in Australia and emphasises the need for concurrent habitat enrichment programs when removal of exotic vegetation takes place. (*The Victorian Naturalist* 132 (4) 96–107)

Keywords: biodiversity, invasive taxa, macroinvertebrates, *Salix*, willow roots

Introduction

Habitat diversity has been correlated with high macroinvertebrate diversity (Schiemer *et al.* 1991; Minshall 1988; Harper *et al.* 1992; Minshall and Robinson 1998) suggesting loss of habitat complexity due to river channelisation and removal of riparian vegetation, which will adversely affect macroinvertebrate richness, abundance, biomass and diversity. This suggests that care is required where clearing of already established exotic riparian vegetation is undertaken. Recognition of available habitat structures or the presence of surrogate habitat structures is important for appropriate management.

There are many examples from marine and freshwater environments where a positive increase in diversity has been achieved through habitat manipulations. Artificial reefs and other habitat structures are widely used to improve marine habitats to improve fisheries (Russell 1976; Talbot *et al.* 1978; Burchmore *et al.* 1985). Bell *et al.* (1985; 1987) used artificial sea grass units to increase recruitment of post larval and juvenile fish and crustaceans to estuaries around Sydney, NSW. Koehn (1987) showed increase in fish abundance in a stretch of the Ovens River, in north-eastern Victoria, after it had been seeded with large rocks. Snags have been identified as important habitat for inver-

tebrate and vertebrate biodiversity (Borchardt 1993; Phillips and Kilambi 1994). Habitat enhancement through planting of willow *Salix* sp. and Common Reed *Phragmites australis* in off-channel bays in parts of the Huntspill River, Somerset, England, resulted in a significant increase in abundance and diversity of fish (Langer and Smith 2001).

Willows were introduced to Australia during the early 19th century and became naturalised. They have spread across approximately 30 000 km of the 68 000 km river frontage in Victoria (Ladson *et al.* 1997). The impacts of willows on stream channel morphology have been widely researched (e.g. Young 1980; Ladson *et al.* 1997); but little research has been carried out to understand their effects as habitat. Willows have a characteristic complex root system that often grows into the stream channel and is different from the root system of most native riparian tree species. Where willows are dominant, their roots cover a large area of the littoral zone of channels. These root mats can be considered as a novel littoral habitat. Studies in the Murrumbidgee River near Wagga Wagga, NSW (Robertson 1993) revealed that exposed inundated roots formed patches of habitat providing shelter, food and oviposition sites for

diverse aquatic macroinvertebrates while bare banks were inhabited by only thinly scattered oligochaetes and chironomids. Boulton and Lloyd (1991) also found bare banks to be poor microhabitat in the lower Murray River compared to root habitats. Their conclusions were based on a study of only two seasons of the year. Jayawardana and Westbrook (2010) and Jayawardana (2011) compared macroinvertebrate communities of root habitats provided by willows with those provided by native vegetation and found differences in species composition. No comprehensive study has been carried out to investigate the contribution of willow roots as a habitat for macroinvertebrate communities in places where other vegetation is lacking. In the management of invasive riparian vegetation, it is important to understand the habitat function of these introduced species and their ecosystem functions to aid management and habitat remediation. Therefore, the objective of this study was to investigate how macroinvertebrate communities use willow root mats as a habitat compared to open bank habitats. Macroinvertebrate richness, abundance, biomass, diversity and assemblages associated with willow root mats and open bank habitats were compared in three Central Victorian streams during summer, autumn, winter and spring of 2004.

Materials and methods

Study sites

Birch Creek, located in the north central region of Victoria, is a major tributary of the northward flowing Tullaroop Creek system in the upper catchment of the Loddon River. The riparian vegetation includes native *Eucalyptus* spp., *Acacia* spp., *Callistemon* spp., *Leptospermum* spp. and exotic *Salix* spp. (willows), with intermittent reed-dominated stretches. The dominant land uses adjacent to the creek are grazing and cropping. Jim Crow Creek is also a tributary of the Loddon River, containing native vegetation, exotic willows and intermittent reed beds. It flows largely through public land. The East Moorabool is a branch of the Moorabool River, which originates in the Great Dividing Range in Central Victoria. It flows through native forest and agricultural areas and has stretches dominated by willows and native vegetation (Fig.1).

Sampling

Two sites (100 m reach) were selected for sampling in each of three rivers (4th to 5th order), each site having stretches of willows and bare banks. Six samples were collected from each habitat type. Sampling was carried out during summer, autumn, winter and spring using a 20 cm × 20 cm horizontal metal frame attached to a sampler with a 250 µm mesh net. The area inside the sample frame was excavated to 5 cm depth and the whole sample, together with the portion retained in the net as a result of site disturbance, was collected and sealed in a polythene bag. All samples were transported to the laboratory for sorting. Dissolved oxygen, pH, conductivity, temperature and flow also were recorded in each instance. In the laboratory, samples were sieved (minimum sieve size 250 µm) and macroinvertebrates were separated and preserved in 70% alcohol. The species present in each sample were identified to the lowest possible taxonomic level (Cranston 1996; CSIRO 1999; Gooderham and Tsyrlin 2002; Hawking and Theischinger 1999). The live willow roots were separated and the remaining fraction of the sample was separated into coarse particulate matter fraction (CPOM) (>1 mm) and fine particulate matter fraction (FPOM) (1 mm–250 µm), air dried for 24 hrs and oven dried at 105°C until constant weight was attained. After recording the dry weight, each fraction was ashed at 550°C for six hours and ash free dry weight (AFDW) was recorded for each fraction. CPOM and FPOM content were calculated for each sample and percentages of CPOM and FPOM were calculated.

Analysis

A total of 288 samples were collected over the four seasons. The data were analysed using multifactorial ANOVA with season, river and habitats within sites as main effects. Differences in species richness, total abundance and Shannon Diversity Index (SDI) between habitats were assessed using multifactorial ANOVA in the R package (R Development Core Team 2004). Total abundance values were log transformed [$\log(I+x)$] before analysis to counteract the effect of highly dominant taxa.

Macroinvertebrate community assemblage differences were assessed using Canonical

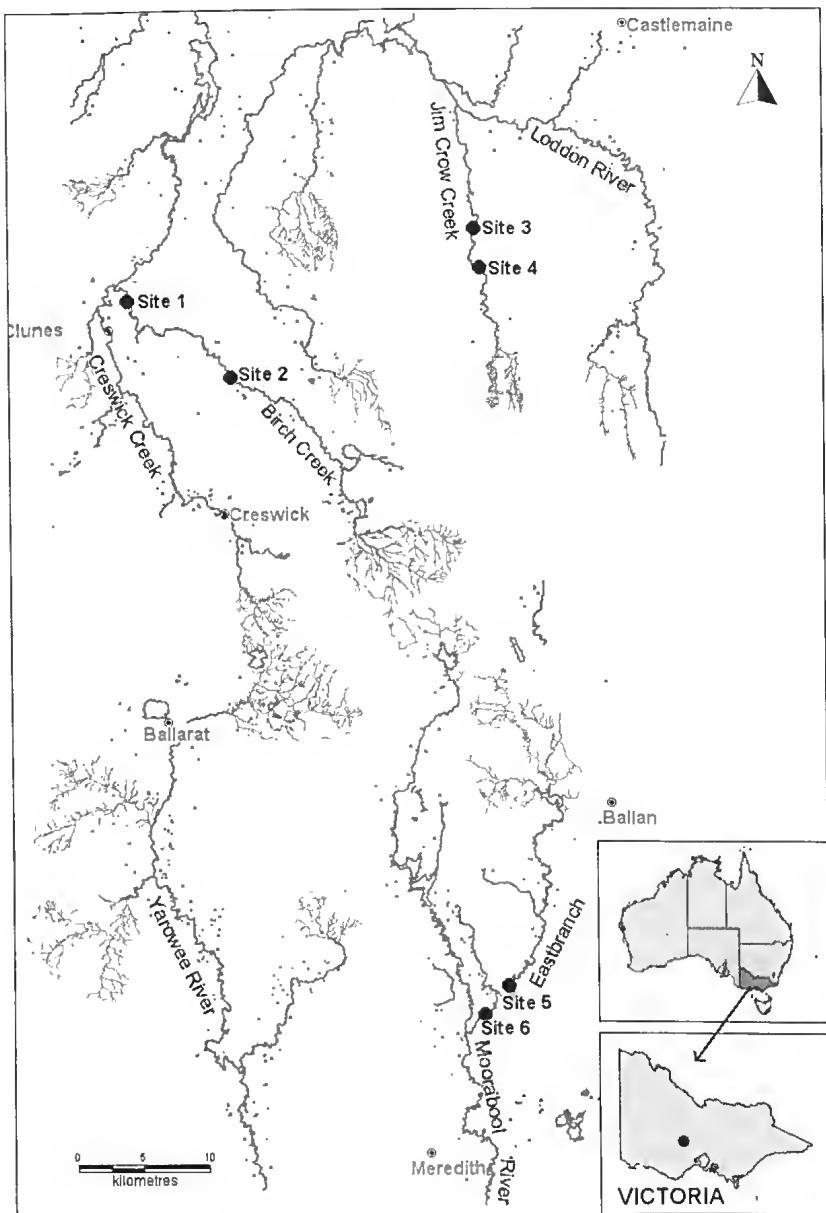


Fig. 1. Sampling sites of Birch Creek, Jim Creek and Moorabool River

Analysis of Principle Co-ordinates (CAP). This technique allows (i) testing for differences among assemblages (ii) identification of taxa most highly associated with the effects of habitats (iii) visualisation of the between and within group variation and (iv) a discriminant analysis (Anderson and Willis 2003; Anderson and Robinson 2003).

CAP analysis of communities was conducted in two ways. First, discriminant analysis was conducted to discriminate between habitats (willow and bare banks) for each river during different seasons. Confusion tables ([mis] classification rates) were also generated. Secondly, CAP was used to determine taxa associated with each habitat type. For that, CAP analysis was conducted for two habitats using the data pooled across three rivers in each season separately. The taxa highly associated with habitat type were identified using correlation between the individual taxon abundance and the canonical axis separating habitats. To calculate the mean correlation value for each taxon, these correlations were averaged across seasons. To examine the community gradients, Principle Coordinates Analysis (PCoA) (Gower 1966) was employed and indirect ordination plots were generated. Both CAP and PCoA were conducted using the CAP package developed by Anderson (2003). In all cases, the Bray-Curtis dissimilarity coefficient was used.

Results

Physical and chemical parameters associated with sampling sites

The physical and chemical characteristics of sites are summarised in Fig. 2. Flow occurred in all three rivers during winter and spring but there was very little or no flow throughout summer and autumn. Bank habitats had higher flow than willow root habitats during winter and spring when average river flow was highest. Percentage CPOM amount in willow root habitats were higher than in bare bank habitats throughout all seasons. Percentage FPOM showed the same trend within two of the three rivers. Slightly lower dissolved oxygen levels were recorded in willow root habitats during summer and autumn seasons. Slight reduction in temperature was detected in willow root habitats during summer. Conductivity and pH did

not show significant variation between habitats; however, these parameters varied significantly across seasons, rivers and sites.

Effect of habitat on macroinvertebrate taxa richness, abundance, biomass and diversity

There was a significant effect of habitat on species richness and log abundance ($p>0.05$) but this was not consistent across the different rivers during different seasons of the year ($p<0.05$ for season \times river \times habitat three-way interaction). Therefore, analysis was carried out separately for the different rivers and seasons. Willow root mats had higher species richness for most sites in all seasons. Total abundance of taxa showed a similar trend (Figs 3a and 3b).

Macroinvertebrate biomass also differed significantly ($p<0.05$) between the two habitats. In all seasons, macroinvertebrate biomass was higher in willow root habitats (Fig. 3c).

Shannon Diversity Index (SDI)

SDI also showed significant differences between habitats ($p<0.05$). However, a significant river \times habitat and season \times habitat interaction also was observed in the analysis. Therefore, analyses were conducted separately for the different rivers during different seasons. Pair-wise comparisons indicated an inconsistent pattern of SDI between the two habitats during different seasons (Fig. 3d).

Effect of habitat on macroinvertebrate community assemblages

Willow root habitats and bare bank macroinvertebrate community assemblages showed significant differences ($p<0.05$) in all sites between seasons. Correlations of taxa with canonical axes showed that eight taxa were associated with willow root mats (mean correlation coefficient >0.2). Ten taxa were moderately associated with root habitat (mean correlation coefficient >0.1) (Table 1).

In contrast, four taxa were associated with bare bank habitats (correlation coefficient >0.2) and ten taxa were associated with bare bank habitats (correlation coefficient >0.1) (Table 1).

Discussion

The differences in physico-chemical parameters associated with willow roots and bare bank habitats can be explained by the structural differences of the two habitats. Flows recorded

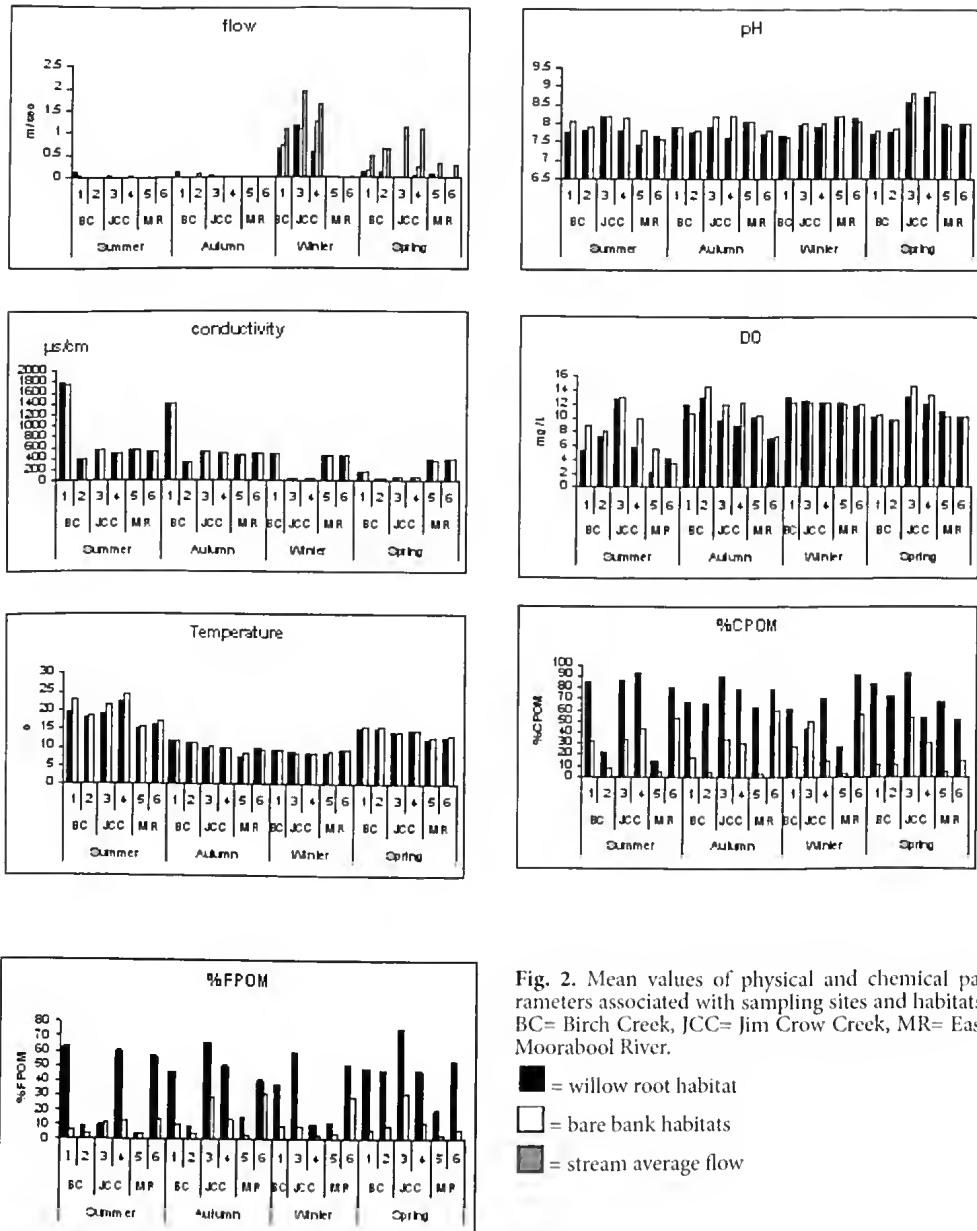


Fig. 2. Mean values of physical and chemical parameters associated with sampling sites and habitats. BC= Birch Creek, JCC= Jim Crow Creek, MR= East Moorabool River.

- = willow root habitat
- = bare bank habitats
- ▨ = stream average flow

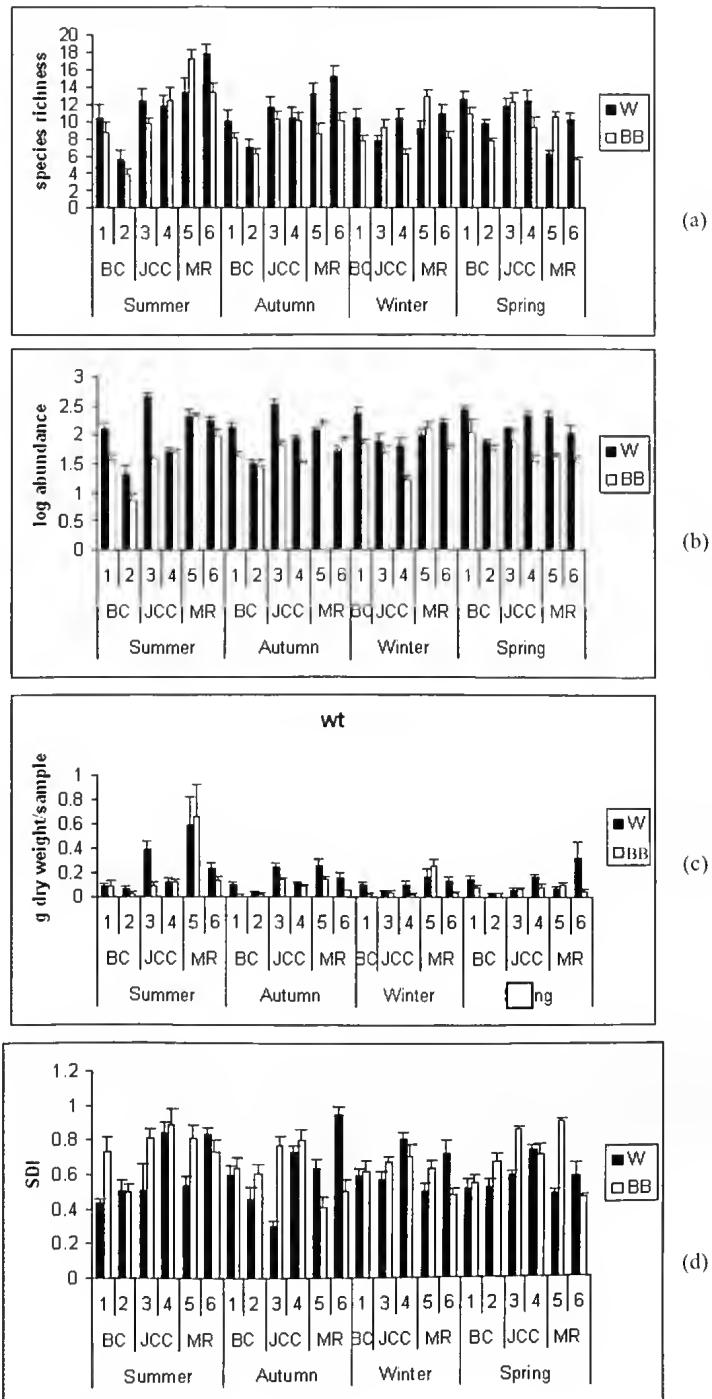


Fig. 3. Mean \pm SE of (a) species richness, (b) log abundance, (c) Biomass, and (d) SDI of macroinvertebrates, associated with willow root habitats and bare bank habitats during four seasons of the year.

■ = willow root habitat
□ = bare bank habitats

(c)

(d)

Table 1. Taxa association with willow root habitats and bare banks from CAP analysis. (Values indicate correlation coefficient of taxa with canonical axis, blank space = taxon not recorded; positive values indicate a location of willow root habitats and negative values a location of bare bank habitats)

Habitat	Family	Genus/Species	Taxa				Mean
			Summer	Autumn	Winter	Spring	
willow roots	Ceinidae	<i>Austrochiltonia</i> sp.	0.38	0.31	0.27	0.49	0.36
	Coenagrionidae		0.23	0.23	0.29	0.41	0.29
	Talitridae		0.01	-	-	0.29	0.29
	Planorbidae	<i>Gyraulus</i> sp.	0.01	0.31	0.35	0.42	0.28
	Lymnaeidae	<i>Glyptophysa</i> sp.	0.05	0.25	0.29	0.4	0.25
	Paramelittidae	<i>Antipodetus</i> sp.	0.3	0.36	0.23	0.08	0.24
	Hydrobiidae	<i>Potamophrygus</i> sp.	0.16	0.31	0.02	0.36	0.21
	Parastacidae	<i>Cherax destructor</i>	0.26	0.19	0.14	0.23	0.2
	Ephydriidae		-	0.2	-	-	0.2
	Leptophlebiidae	<i>Cura</i> sp.	0.09	0.24	0.11	0.31	0.19
	Lymnephilidae	<i>Atalophlebia australis</i>	0.05	0.21	0.2	0.27	0.18
	Corduliidae	<i>Sp b</i>	-	0.14	0.21	-	0.17
	Lymnephilidae	<i>Sp c</i>	0.19	0.27	0.1	0.09	0.17
	Syrphidae		-0.01	0.24	0.13	0.28	0.16
	Aeshnidae		-	-	0.15	-	0.15
	Hydropsychiidae		0.21	0.06	0.16	0.18	0.15
	Physidae		0.1	0.18	0.13	-	0.14
	Simuliidae		0.11	0.38	0	0.05	0.14
	Sciirtidae	<i>Phylsa acuta</i>	0.1	0.03	0.22	0.18	0.13
	Ecnomidae	<i>Scirites</i> sp.	0.03	0.26	0.12	0.11	0.13
	Veliidae	<i>Ecnomus</i> sp.	0.02	0.08	0.24	0.08	0.11
	Leptoceridae		0.16	0.04	-	0.12	0.1
	Leptophlebiidae		0.22	-0.05	0.03	0.18	0.1
	Polycentropodidae		0.06	-	-	0.13	0.09
	Megapodagrionidae		0.09	-	-	-	0.09
	Lymnephilidae		-	0.08	-	-	0.08
	Haplotoxidae		-0.03	0.04	-	0.23	0.08
			-	-	0.08	-	0.08

Table 1, cont'd

Habitat	Taxa		Genus/Species	Summer	Autumn	Winter	Spring	Mean
	Family	Genus						
Elmidae (larvae)			0.03	0.23	0.04	0.01	0.08	
Calamoceratidae			0.1	0.05	-	0.06	0.07	
Planorbidae			0.03	0.1	-	-	0.07	
Megadrili		<i>Pygmanitus</i> sp.	0.05	0.24	-0.09	0.06	0.06	
Hydrobiidae			0.1	0.2	0	-0.04	0.06	
Tanypodinae		<i>Potanophrygus</i> sp.	0.07	0.16	-0.1	0.12	0.06	
Caenidae			0.02	-	-	0.1	0.06	
Gomphidae		<i>Tasmanoacanis</i> sp.	0.06	-	-	-	0.06	
Petaluridae			0.06	-	-	-	0.06	
Leptoceridae			0.15	-0.04	0.05	-	0.05	
Elmidae (adult)		<i>Triplectidius</i> sp.	-0.15	0.22	0.07	-	0.05	
Janiidae			0.09	-0.03	0	0.13	0.05	
Haliplidae			0.05	-	-	-	0.05	
Hydroptilidae		<i>Haliplus</i> sp.	-0.19	0.05	0.14	0.18	0.05	
Odontoceridae			0.06	0.22	-0.13	0.02	0.04	
Leptoceridae			-	0.04	-	-	0.04	
Leptophlebiidae		<i>Oecetes</i> sp.	0.03	-	-	-	0.03	
Atriplectidae		<i>Thraulus</i> sp.	0.1	0.05	0.03	-0.06	0.03	
Gripopteryidae		<i>Atriplectides</i> sp.	-0.02	-0.18	0.01	0.31	0.03	
Chironominae		<i>Lepioptera</i> sp.	0.16	0.04	0.16	-0.20	0.02	
Dytiscidae			-0.01	0.14	-0.01	-0.02	0.02	
Caenidae		<i>Rhantus</i> sp.	0.17	-0.15	0.15	-0.08	0.02	
Leptophlebiidae		<i>Wundacaenis</i> sp.	-0.06	0.1	-	0.02	0.02	
Glossiphoniidae			0.02	0.1	0	-0.03	0.02	

Table 1. cont'd

Habitat	Family	Taxa	Genus/Species				Mean
			Summer	Autumn	Winter	Spring	
Bare banks	Sphaeridae	<i>Sphaerium sp.</i>	-0.03	-0.44	-0.23	-0.29	-0.25
	Psephenidae	<i>Sclerocyphion sp.</i>	-0.37	-0.03	-	-0.27	-0.22
	Empididae		-0.22	-	-	-	-0.22
	Tubificidae	<i>Branchinella sowerbyi</i>	-0.02	-0.41	-	-	-0.21
	Tubificidae	<i>Sp.</i>	0.2	-0.37	-0.41	-0.2	-0.2
	Corixidae	<i>Micronecta sp. (nymph)</i>	-0.37	-0.08	-	-0.06	-0.17
	Lynnephilidae	<i>Sp. d</i>	-0.03	-	-0.26	-	-0.15
	Phreodrilidae	<i>Antarctodrilus proboscideus</i>	-	-0.26	-0.04	-	-0.15
	Siponotidae		-	-0.14	-	-	-0.14
	Ancylidae	<i>Ferrissia sp.</i>	-0.43	-0.07	0.1	-0.14	-0.14
	Sphaeridae	<i>Pisidium sp.</i>	0.07	-0.17	-0.13	-0.28	-0.13
	Tipulidae		-0.03	-	-0.29	-0.06	-0.13
	Capillariiventridae		-	-0.12	-	-	-0.12
	Dytiscidae	<i>Necterosoma sp.</i>	-0.11	-0.05	0.07	-0.35	-0.11
	Leptophlebiidae	<i>Atalophlebia australisica</i>	-0.1	-	-	-	-0.1
	Lumbriculidae	<i>Lumbriculus variegatus</i>	0.06	-0.14	-0.13	-0.2	-0.1
	Psychidae		-0.1	-	-	-	-0.1
	Corbiculidae		-	-0.13	0	-	-0.07
	Bactidae		0.04	-0.16	-0.19	0.03	-0.07
	Phretoidae		0.06	0.04	-0.11	-0.22	-0.06
	Ceratopogonidae		0	-0.07	0.08	-0.24	-0.06
	Corixidae	<i>Micronecta sp. (adult)</i>	0.05	-0.23	0.22	-0.23	-0.05
	Dytiscidae (larvae)	<i>Sympitoneuria sp.</i>	-	-0.04	-	-0.04	-
		<i>Leichhardt sp.</i>	-0.02	-0.05	-0.03	-0.07	-0.04
	Lymnaeidae	<i>Glyptophysa sp.</i>	-0.04	-	-	-	-0.04
	Atyidae	<i>Paratya australiensis</i>	0.03	-0.1	-	-	-0.03
	Odontoceridae	<i>Sp. a</i>	0.06	-0.1	-0.24	0.14	-0.03
			0.08	0.12	-0.05	-0.21	-0.02

Table 1. cont'd

Habitat	Family	Taxa	Genus/Species	Summer	Autumn	Winter	Spring	Mean
Saltidae	Lymnaeidae	<i>Glyptophysa smooth</i>	0.13	-0.18	-	-	-	-0.02
	Lestidae	<i>Austrolestes analis</i>	-0.04	0.05	-0.06	-0.04	-0.02	
	Notonectidae	<i>Enithares sp.</i>	-0.02	-	-	-	-0.02	
Brentidae	Berothidae	<i>Berothus sp.</i>	-0.22	0.05	-0.02	0.12	-0.02	
			-	-	0	-	0	
				-0.01	-	-	-	-0.01

in willow root habitats during winter and spring were comparatively lower than in bare bank habitats in most sites sampled, suggesting that willow roots would act as mechanical barriers and filter suspended material. Higher amounts of CPOM and FPOM occurred in willow root habitats compared to bare bank habitats, even in winter when willows had lost their leaves, further confirming that willow root mats filter suspended material. The relatively reduced temperature levels recorded in willow habitats in summer would be due to the shading effects of the canopy (Pidgeon 1978; Glova and Sagar 1994). The lower dissolved oxygen levels of willow root habitats during summer and autumn can be related to the increased levels of organic matter coupled with reduced stream flow in these seasons. Increased community respiration coupled with reduced dissolved oxygen levels associated with stagnant water created an oxygen gradient between the two habitats. This also could have been affected by the heavy shading of willow habitats during summer and autumn as willows would have had a full canopy that would have reduced the photosynthetic algal growth under willows compared to open bank habitats (Pidgeon 1978; Glova and Sagar 1994).

The interaction of season, river and habitat on species richness and abundance indicates that the effect of habitat is not consistent in different rivers during the different seasons. These differences may be due to inherent heterogeneity of available resources or patchiness of each river, and governed by their flow regimes. Willow root habitats are more favourable for macroinvertebrates in terms of food availability and refuges compared to mineral substrate. Similarly willow root mats act as mechanical barriers, which prevent the effects of high flow and stabilise structures for their attachment compared to the more unstable mineral substrates. Total abundance of taxa showed inconsistent patterns from site to site, probably due to the different compositions of taxa in different habitats. Some micro levels of physico-chemical parameters favour the abundance of particular taxa, which leads to their dominance, creating more variability in total abundance between sites. Besley (1992) compared riparian root habitats of River Red Gum *Eucalyptus camaldulensis*, River Oak *Casuarina cunninghamiana*, and White Willow *Salix alba* with bare bank habitats and showed that riparian root habitats supported significantly more species than bare bank habitats during autumn and

winter. Results of the present study were consistent with these findings.

Total biomass of taxa was consistent in willow root habitats and bare bank habitats during all seasons and rivers, although higher biomass of taxa was observed in willow root habitats in all seasons. Glova and Sagar (1994) showed higher species richness, total abundance and biomass of benthic invertebrates associated with willow than non-willow sections, consistent with our results. The increase of fish abundance associated with willow habitats in the previous study may be attributed to the higher food levels associated with willow habitats.

SDI is more affected by the presence and abundance of taxa. Lowered levels of SDI in willow root habitats in some sites indicate that few taxa dominate that habitat. This suggests that willow root mats favour particular taxa and their abundance. Organic matter enrichment in willow root habitats favours pollution tolerant taxa by replacing more sensitive taxa groups (Suter 1990). Fauna of willow root mats was dominated by deposit feeding collectors such as Oligochaetes and Amphipoda (Latta 1974). Plecoptera, Trichoptera and Ephemeroptera, which respire with gills or direct cuticular exchange, can be particularly susceptible to lowered dissolved oxygen levels (Dallas and Day 1993) and the taxa which were missing from willow sites in summer were consistent with this pattern.

Most taxa showed higher association with willow root habitats during autumn when most of the allochthonous organic matter in the form of food from willow reaches the stream. The differences in community assemblages observed in the two habitats can be related to many factors. Amphipoda (Paramelitidae), a relatively large group of shredders, was the dominant group in willow root habitats in all seasons and were highly associated with willow root habitats during autumn, suggesting an association with CPOM content. Ceinidae were highly associated with willow root habitats during most of the seasons suggesting that they are dependent on FPOM or decaying root mats or have a structural preference for this habitat. The higher association of more organic pollution tolerating taxa, such as *Potamopyrgus* sp., *Cura* sp., *Megadrilus*, *Physa acuta* and shredders such as Amphipoda, with willow root habitats during autumn in this

study suggests that they prefer organic matter enrichment available from willows during autumn. The higher association of ambush predators, such as Coenagrionidae, with willow root mats suggests that predators also benefit from the complex structures of root mats.

Simulium sp. and *Leptoperla* sp. showed moderate mean correlations during winter and spring. *Simulium* sp. uses cephalic fans for capturing food items and may prefer the higher flows of winter, which facilitate its food capturing habit. *Leptoperla* sp. was also highly associated with willow roots during winter and spring. Its preference for this habitat may be related to well-oxygenated fine particulate organic matter in the rich willow root environment. Some grazers, such as *Gyraulus* sp., *Glyptophysa* sp., *Potamopyrgus* sp., were associated with willow root habitats during winter and spring, benefiting from periphyton and biofilm associated with willow root mats under the open canopy of willows and from the stable substrate of willow root mats, which provide refuge during high flow.

In contrast, *Sphaerium* sp., Psephenidae, Tubificidae, Corixidae, Phreodriliidae, Aencylidae, *Pisidium* sp., Tipuliidae, Capilariventridae, Dytiscidae, Lumbriculidae, and Leptophlebiidae were highly associated with open bank habitats. Their association with mineral substrate may be related to their food acquiring behaviour. Most of them are filter collectors, which benefit through such mineral substrate and associated suspended organic matter. Some predators such as Corixidae and Dytiscidae are also associated with bare bank habitats.

This evidence suggests that willow root mats are productive habitats compared to open bank mineral substrates. This habitat supported distinct macroinvertebrate communities and higher species richness and biomass compared to bare bank habitats. This suggests that removal of willows from streams where other riparian cover is lacking can have detrimental effects on stream macroinvertebrate communities. Boulton and Lloyd (1991) suggest the need of alternative mechanisms to improve habitat heterogeneity where willow removal takes place. Further research is needed to understand alternative methods, such as macrophytes, snags or fast growing vegetation cover, e.g. reeds, would all be effective in improving habitat heterogeneity.

neity and thus biodiversity in streams where willow removal is taking place.

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Account of a mass aggregation of Port Jackson sharks *Heterodontus portusjacksoni* at Point Cooke Marine Sanctuary, Victoria, Australia

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Abstract

In January 2009, a mass aggregation of over 100 Port Jackson sharks *Heterodontus portusjacksoni* was noticed during a recreational snorkel at the Point Cooke Marine Sanctuary. The sharks (which all appeared to be female) were observed over two consecutive days in January 2009, after which they evidently departed en masse. The habitat being used at Point Cooke Marine Sanctuary appeared to be different from that typically used by this species (which from literature sources appears to include caves and rock ledges that allow sharks to be 'tucked away' and difficult to access). The reasons for the aggregation are unknown, but no sharks were observed to be actively foraging at the time of the aggregation, nor participating in any mating or egg-laying behaviour, suggesting that a male avoidance strategy may have been implemented by these animals. (*The Victorian Naturalist* 132 (4), 2015, 108–117)

Keywords: Port Jackson sharks, *Heterodontus portusjacksoni*

Introduction

A mass aggregation of over 100 Port Jackson sharks (*Heterodontus portusjacksoni*) was noticed during a recreational snorkel at the Point Cooke Marine Sanctuary over two consecutive days in January 2009. This account aims to describe what appears to be a relatively very unusual occurrence, since in the literature there are virtually no recorded or documented instances of mass aggregations of this size and type.

Dates of sightings

The sharks were first observed at approximately 11:00 on Sunday, 4 January 2009 during a routine recreational snorkel. The sharks were still present during another snorkel at around 2.00 pm on the same day, and were also found at approximately 1:00 pm on Monday, 5 January 2009, but all had left the area by approximately 10.00 am on Tuesday, 6 January 2009. To summarise, four recreational free dives were conducted, and the sharks were present during three of them. It is unknown how long these sharks had actually remained in this location prior to the initial sighting on 4 January, and all observations described herein were conducted opportunistically and were not part of a defined sampling program.

Location and habitat of shark aggregation

The approximate location of this sighting at the Point Cooke Marine Sanctuary was 37°55'24.52"S and 144°47'58.62"E (Fig. 1).

The aggregation occurred off the south-eastern side of the shore near emergency location area PCC506, near the Point Cooke Homestead, placing it within Altona Bay (Fig. 2). The area was between 50 and 80 metres offshore, past a number of rocks in the shallow intertidal zone that exhibit heavy coverage of the calcareous tubeworm *Galeolaria caespitosa*, and also features an intertidal seagrass meadow.

Access to this site was easily made by walking to the eastern side, thus avoiding trampling the seagrass beds as well as the boulders, which are festooned with sea urchins and thus present a potential injury risk to waders.

The majority of sharks were found in water of 1.5 and 2 metres depth, depending on bottom topography. The benthos in this area consists of basalt reef and boulders, interspersed with sand patches and extensive colonisation by the green algae *Ulva* spp. (Fig. 3).

No ontogenetic (age) differences in habitat use were noted on this occasion, with the distribution of sharks according to size appearing to be random.

The section of the Point Cooke Marine Sanctuary that the sharks were residing in during their mass aggregation does not feature dense coverings of macroalgae; the dominant algal species in the area tend to be the southern sea

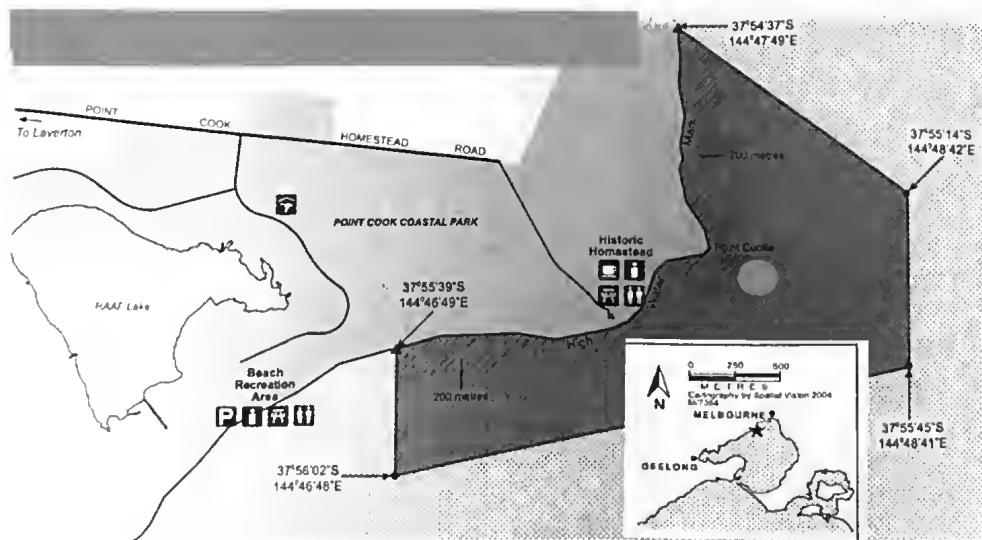


Fig. 1. Approximate location of the shark aggregation, as indicated by a red circle. Location of the suburb of Point Cook is demonstrated by the position of the star on the map inset (Photo: modified from Parks Victoria, 2004).



Fig. 2. View from PCC506 at low tide from the shore. The emergency location sign appears at the right, with a sign on the left indicating that the location is Point Cook. The aggregation of sharks appeared to the left side (to the south-east) of the intertidal area.



(a)



(b)

Fig. 3. The location where the sharks were sighted, as viewed from under the water, (a) with boulders and rocky bottom; and (b) with intermittent sand patches.

lettuce *Ulva rigida* and/or *U. australis*, and *Sargassum* spp. is also common, while at the time of the sighting, the invasive marine pest species *Undaria pinnatifida* (Japanese kelp or Wakame) was in a state of dieback. As it stood, none of these macroalgal species would have provided appreciable levels of shelter. This, combined with the shallowness of the water, meant that all animals were very exposed to the solar radiation that was present at the time.

Very high solar radiation readings were recorded on both days (34.8 and 34 MJ/m² on Sunday and Monday respectively) (Data: Bureau of Meteorology) that the sharks were sighted, due to the time of year (summer), the consequently long photoperiod, and the minimal cloud cover that was present during the times the observations were made.

Prevailing conditions

Bureau of Meteorology data from the nearby Laverton RAAF base for the days that the

Table 1: Daily maximum and minimum temperatures and rainfall totals for the period around the sighting of the shark aggregation (Source: Bureau of Meteorology).

Date	Day	Maximum air temperature (°C)	Minimum air temperature (°C)	Rainfall (mm)
3 January 2009	Saturday	19.2	6.5	0
4 January 2009	Sunday	24.7	7.2	0
5 January 2009	Monday	25.6	9.4	0
6 January 2009	Tuesday	29.8	12.4	0

sharks were observed to be *in situ* and a day either side of the aggregation being noted is shown in Table 1.

The wind during all days in which observations were conducted was relatively light, with seas being calm and wave heights generally below 0.5 m. Tidal heights varied between a low of 27 cm to a high of 88 cm while the sharks were present at the aggregation site.

The contention from several authors (including Last and Stevens, 1994) that the species generally returns to rocky gullies and caves during the day appeared to be flouted on the days in question by the animals in this aggregation, as the sharks stayed in the same area for at least 48 hours during day time and presumably also at night time, given the sheer size of the aggregation.

On 3 January illumination from the moon was 37.7% of that from a full moon, increasing to 48.4% and then 59.5% on the two days that the aggregation was observed. This increased further to 70.5% (Timeanddate.com website, <http://www.timeanddate.com/moon/australia/melbourne>) on the day the sharks were no longer observed in the area. Sunday 4 January marked the start of the first quarter lunar phase, with a full moon appearing on 11 January, well after the sharks had left the area (Data: Planetarium, Museum Victoria website, <http://museumvictoria.com.au/planetarium/discoverycentre/moon-phases/>)

Shark numbers

The school of sharks in this case was estimated to number well in excess of 100 individuals, an estimate that was made easier based on their generally docile and stationary disposition, and the relatively small area that they were found to inhabit. One area that was observed to be bare-

ly 5 m × 5 m or 25 m² contained 27 sharks, with many stacked one on top of the other. The total area that the sharks occupied was difficult to estimate because of the patchy distribution of the sharks, though there was not much distance between sharks in adjacent areas. The aggregations on both days seemed to be of similar size.

Shark sex and size

The Port Jackson shark, like all elasmobranchs, features obvious sexual dimorphism in that males and females can be distinguished readily upon examination of their genitalia. Claspers on the males of this species, like those of many elasmobranchs, are prominent (Fig. 4), and none were seen. In this instance, shallow water made lateral observations possible; these are useful for providing additional qualification of the sex of the sharks. Claspers on male animals may be difficult to detect if the shark is stationary and the claspers sit in line with the body and are concealed by the shark's dorsal surface; objects that may be present in the benthos, such as rocks and macroalgae, may also hinder observations. In this case it certainly appeared that all animals observed were in fact female. While the author did not survey every single shark in the mass aggregation, and it is therefore possible that males could have been concealed amongst the school, it is certain that these males would have represented an extreme minority, if they were present at all.

Lengths of the sharks varied between 40 cm and 120 cm, with no specific size segregation apparent.

Shark behaviour

All sharks were observed to be extremely docile, with very few sharks actively swimming; their behavioural pattern can therefore be de-



Fig. 4. The claspers of a male Port Jackson shark (total length approximately 70 cm) photographed at nearby Ricketts Point Marine Sanctuary.

scribed accurately as 'resting'. No foraging was observed to be taking place.

On a couple of occasions some sharks were observed to swim away when approached, but this was to be expected considering the size of the observer (approximately 181 cm tall and 79 kg, and the additional length of the flippers) being considerably larger than any of the observed sharks. Sharks that did relocate generally swam only a very short distance (10 metres or less) before settling again on the benthos. At no stage did the author ever feel threatened by the sharks, with no aggressive or even investigative approaches instigated. No sudden or erratic movements were made by the author, and all movements towards sharks were very slow and deliberate, so as not to alarm the animals.

Other occurrences of Port Jackson sharks and other elasmobranchs at Point Cooke Marine Sanctuary

Prior to this occurrence, the author had never seen a Port Jackson shark at the Point Cooke Marine Sanctuary, despite snorkelling sporadically in the area between 1997 and November 2005, when the author moved to the area and then snorkelled regularly, up until the present time. Only a few other Port Jackson sharks have been seen since the mass aggregation, with another sighting of a female made on 24 October

2009. In this incident, the shark appeared to have her head down amongst some rocks and was making twisting motions with her body, which assumed a nearly vertical attitude suspended in the water column. This could have been suggestive of either foraging behaviour or the planting of an egg case, though no evidence of either was found upon examination of the benthos where her head had been. The month of October fits with Stevens' (1987) assertion that this period is when the laying of eggs takes place. Another female (possibly gravid on account of a somewhat distended abdomen) was sighted during September of 2014 (Fig. 5).

In addition to sightings of sharks, the occasional egg case has been found washed up on the beach (Fig. 6), even though these have generally not been in very high numbers, with only a few sighted over the years. This would seem to indicate that Point Cooke Marine Sanctuary is not a very well frequented area, and certainly not a residential haunt, of this particular species.

The low number of sightings of Port Jackson sharks in the shallows of the Point Cooke Marine Sanctuary must be considered a true indication of their general lack of presence in this area, since experienced snorkellers and divers are able to spot similarly sized animals such as stingrays and stingarees even when only the eyes and spiracles (accessory breathing organs)



Fig. 5. A female Port Jackson shark sighted near the location of the mass aggregation several years later in September 2014.

are visible. It appears that Point Cooke Marine Sanctuary is something of an elasmobranch haven, with at least six species of ray having been sighted within the boundaries of the sanctuary, including the Southern Fiddler Ray *Trygonorrhina dumieri*, which is extremely common during the summer months in particular, and the eastern shovel-nose stingaree *Trygonoptera imitata*, and Sparsely Spotted Stingaree *Urolophus paucimaculatus*, which can also be found in considerable numbers in the sanctuary. Also encountered are the Southern Eagle Ray *Myliobatis australis*, the less common Spotted Stingaree *Urolophus gigas* and the Smooth or Short-tailed Stingray *Dasyatis brevicaudata*. Other shark species sighted in the Point Cooke Marine Sanctuary include the Gummy Shark *Mustelus antarcticus*.

Observations of marine life during the summer months are generally limited by the prevailing weather conditions. During hot and sunny days, the norm is for northerly winds to flatten out the surface of Port Philip Bay in this location during the morning hours, thus allowing greater visibility. During the afternoon, however, sea breezes from the south tend to prevail and cause greater wave swash and surge, reducing visibility.

On the occasions of these sightings visibility was found to be between 4 and 6 metres, which is relatively good for the location, with absolute maximum visibilities observed to be around 10 to 12 metres. Unfortunately, the best visibility



Fig. 6. A Port Jackson shark egg case (110 mm long and 74 mm wide), which was found beyond the western boundary of Point Cooke Marine Sanctuary in 2006.

in this section of Port Philip Bay often occurs during the winter months, when elasmobranchs of any type are relatively rare at Point Cooke Marine Sanctuary; they seem to be very common from October to March, and numbers then start dwindling from April right through until September, when they start to return.

Possible reasons for this mass aggregation
There are myriad reasons why this aggregation may have occurred, and as is often the case with opportunistic observations these are necessarily speculative; however, the aggregation of such a large number of individuals is surely worth recording and discussing further.

Location — why Point Cooke Marine Sanctuary?

Ultimately, we can only speculate on why the Port Jackson sharks that formed this massive school chose Point Cooke Marine Sanctuary

Contributions

as their aggregation destination. Hutchins and Swainston (1996) noted that this species prefers protected reef and adjacent sand and weed areas, and noted that several may crowd together in one cave. Point Cooke Marine Sanctuary does not feature caves in the shallow subtidal region, but instead features a mixture of seagrass meadows, sand patches, and basalt reefs with boulder fields and urchin barrens. Boulders and the like could be considered as potentially suitable areas for the laying/planting of the spiralled egg cases that are characteristic of the species, since females tend to lay eggs and then plant them in rock fissures with their mouths on inshore reefs in areas less than 5 m deep (Last and Stevens 1994). Since no oviposition behaviour or the presence of eggs were observed, and apparently all sharks were female, and given that the timing of these observations was outside the expected parturition period for this species, egg laying and breeding can be ruled out as reasons for this mass aggregation, as will be discussed in more detail shortly.

The Port Jackson sharks of Ricketts Point Marine Sanctuary

Areas such as the Ricketts Point Marine Sanctuary, near Beaumaris on the north-eastern side of Port Phillip Bay, are renowned haunts for Port Jackson sharks, and the caves and rock gutters in this area evidently support a resident population of these animals. These sharks appear in the shallow subtidal zone between about July and August, and are present until about February before they move on (Mike Letch pers. comm.).

Anecdotal observations from members of the Marine Care Ricketts Point group noted that the usual population of Port Jackson sharks that inhabit the caves and boulder fields in their area was conspicuously absent during January of 2009 (Mike Letch pers. comm.); it is therefore possible that many sharks from this area may have relocated temporarily to Point Cooke, a distance of approximately 23 kilometres.

Last and Stevens (2009) noted that Port Jackson sharks commenced considerable migrations to southern waters in summer and returned north during the winter. Whether this was part of a large migration of individuals from more northerly climes (and therefore an infiltration

of Port Phillip Bay) is unknown. Future residency studies (which could be carried out by a combination of marine friends groups and scientific research agencies, and involve various tagging methods) would be a worthwhile endeavour to shed more light on movements of the species.

Breeding and oviposition

While Tricas *et al.* (1997) noted that groups of adults moved in and out of shallow water depending on water temperature and breeding conditions, with females and some males moving into shallower water for the purposes of mating, it appears that most of the Port Jackson shark population of Australia's southern waters commence ovulation and mating behaviour between late winter and early spring, while oviposition (egg-laying) tends to occur between late winter and spring (Tovar-Ávila *et al.* 2007). Stevens (1987) noted that females lay 10–16 eggs (meaning the species is oviparous) from late July to early October, favouring traditional sites. The eggs take 9–12 months to hatch after oviposition, and young are sustained by a large yolk sac. In New South Wales, the breeding season tends to occur also between July and November. The current aggregation, therefore, seems to be outside the envelope for these processes (even allowing for differences that may occur in the Victorian population), meaning that they can be all but ruled out as direct reasons for the aggregation.

The fact that no males were observed in this particular aggregation is consistent with the assertion by Whitley (1981) that Port Jackson sharks tend to breed on shallow reefs during winter months, with males migrating seaward during the summer months.

In the aggregation described, it is apparent that the sharks (varying in size between 40 cm and 120 cm total length) did not segregate by size (and therefore, presumably, age). These observations differ from those reported in numerous other studies, which have indicated that size-based segregation (and therefore segregation by maturity level) tends to occur (Tricas *et al.* 1997). The spatial separation of adults and juveniles in many species of elasmobranchs is well recognised, and it must be assumed that this could be due to the potential for cannibal-

ism. Based on its dental morphology and behavioural characteristics, it is highly unlikely that Port Jackson sharks would indulge in cannibalism to any significant degree, and it can be speculated that there is therefore possibly more 'leeway' in the size groupings of this species.

Last and Stevens (1994) noted that this species hatches at a size of 23 cm, with females maturing upon reaching 80–95 cm. Without having attempted to conduct measurements and collect length frequency distribution data, it is difficult to express in percentage terms how many individuals could have been expected to be sexually mature, though the suspicion of the author is that the majority of sharks were longer than 80 cm, meaning that they could have been mature or approaching maturity, while some were considerably smaller than this and were therefore presumably immature.

Feeding

Due to the fact that no feeding was observed at all during three separate observational periods, it is unlikely that feeding played a direct role in this particular aggregation. It is uncertain if sharks reverted to feeding during the night, as all observations were made during daylight hours. Edgar (2008) suggested that Port Jackson sharks are predominantly nocturnal feeders that forage for and prey on invertebrates during the night (an assertion supported by Hodgson (1987) and Whitley (1981)), which may explain why no feeding behaviour was observed throughout the entire aggregation.

It is sometimes suggested that sharks and fish are attracted towards the mouths of rivers with the promise of food that sometimes appears to follow on from high rainfall events. January 2009 was the second driest January on record in Melbourne. In this instance, because of the extremely low rainfall totals that were experienced for the local area, attraction of sharks to the area due to freshwater discharges for the period considered can be ruled out. While the prevailing northerly winds and current systems operating at the time the observations were made could have transported scents and various olfactory cues offshore and potentially drawn sharks to the area, it seems that this is a highly unlikely reason for this particular aggregation.

The Point Cooke Marine Sanctuary contains a wide variety of fauna that have been identified by various authors as being standard in the diet of Port Jackson sharks. Whitley (1981) mentioned that this shark prefers crustaceans, molluscs and echinoderms, particularly sea urchins. All of these species groups are in abundance at Point Cooke, with Sea Urchins *Heliocidaris erythrogramma* being dominant to the extent of creating numerous large urchin barrens (areas that have been stripped of macroalgae and are covered in urchins, even in daylight hours). Powter *et al.* (2010), however, implied that urchins were not as important in the diet as previously thought for this particular species. Dingerkus (1987) noted that the range of Port Jackson sharks was necessarily restricted by their diet, which featured items that were typically found relatively close to shore in temperate and tropical waters. Compagno (1987) noted that the diet of this shark consisted mainly of invertebrates, including seastars, crabs, shrimps, barnacles, marine worms, sea snails and other hard prey items, which are crushed with pavement-like molars towards the rear of the jaws; small fish are also captured and eaten. All of these prey items are in abundance at the Point Cooke Marine Sanctuary, which would therefore seemingly make an excellent foraging and feeding location for this species.

Prior documentation of mass aggregation behaviour in this species

To date there is limited information in the literature regarding very large aggregations (>100 individuals) of this species. Compagno (1984) noted that this species often has 'rest areas', which may be used by as many as 16 sharks at a time, and that the animals could range as much as 850 km from breeding areas. Powter (pers. comm, 2010) indicated that the largest aggregation size he had observed personally after eight years of research was 42 individuals, and acknowledged that aggregations in water depths greater than 30 metres that exceeded 100 individuals occasionally occurred, with some video evidence said to exist that verifies these claims. Rocky gutters have been cited as male avoidance structures by Powter and Gladstone (2008a), and sometimes contain 15 to 20 individuals in a relatively small area (such as a gutter 6 m long).

Contributions

This particular aggregation occurred in an area with topography that could hardly be considered ideal for the purposes of communal male avoidance, as sharks could be relatively easily accessed by interested potential suitors.

While it is possible that some refuge from strong water movements would have been conferred by moving to the shallow subtidal region, it is noteworthy that most currents in the northern section of Port Phillip Bay are relatively minimal when compared to the conditions encountered in the open sea and coastal areas, and any longshore drift and other movement patterns would have been minimal.

Powter and Gladstone (2008a) stated that juveniles often occupy a seagrass nursery in a large coastal embayment, but the aggregation observed on this occasion was not in an area dominated by seagrass, and while some were juveniles it was clear from the total lengths observed that a considerable percentage of the sharks present were adults or were at least approaching sexual maturity.

Surely the most interesting question surrounding these observations is what actually caused the sharks to choose Point Cooke Marine Sanctuary in the numbers that they did, and how the sharks all managed to rendezvous at the same location and 'find' each other. Any discussion here is speculative, but it is likely that a combination of senses (olfactory, electrosensory and possibly even visual) could have been used to get the sharks to their shallow water destination. Hodgson (1987) noted that Port Jackson sharks were bottom dwellers with relatively small eyes, and that vision did not play as important a part as olfaction (smell) and electroreception in feeding and social behaviour. Did sharks respond to olfactory cues that were released upon an increasing number of sharks arriving in the area? It appears certain that at present, we simply do not have answers to this question, but future observations of such aggregations could well yield important clues as we learn more of the biology and behaviour of this fascinating species.

Another question concerns what caused the sharks to move away from the area, presumably *en masse*. It is interesting that when all sharks had left the area the day was fine, sunny and warm, but the following day was considerably

cooler and overcast. It is possible that the animals detected an approaching low pressure system and decided to move from the shallows into deeper water, though this is only speculation.

Future work and documentation — will they return?

Even during the summer months, the beaches around Point Cooke Marine Sanctuary are not very popular with people, and are relatively poorly attended despite the idyllic location and pleasant surrounds. It is therefore entirely possible that aggregations of these animals may have been occurring regularly and gone undetected, which is made more possible by the ban on fishing that has been in force since the early 1990s (though illegal recreational fishing has been observed on a reasonably regular basis within the limits of the Point Cooke Marine Sanctuary). It is hoped that with the formation of a new community group, Marine Care Point Cooke, such aggregations will be documented in the future in greater detail than has been provided here. Equipment procured by this group in recent times includes items such as digital cameras with underwater housings, handheld GPS instrumentation and kayaks, all of which could prove invaluable in documenting future aggregations of this and other species in this particular location. That said, in the six years since the mass aggregation occurred, no other such aggregations have been observed, with only a relatively small number of sharks seen in the area. When considering the patronage of the marine sanctuary and the relatively small area that is covered during a recreational snorkel or SCUBA dive, it is not unlikely that aggregations continue to happen and simply go unnoticed. A number of authors (Whitley, 1981; Dingerkus, 1987) have noted that migration to the same favoured sites (including reefs and even crevices) year after year for the purposes of resting, mating and oviposition could be expected; O'Gower (1995) noted that this was possible on account of the species' outstanding spatial memory.

As noted by Powter and Gladstone (2008a), quantitative studies addressing habitat preferences are required to gain a full understanding of the selection of various habitats by elasmobranchs. Likewise, Powter and Gladstone

(2008b) noted that significant aspects of the reproductive biology and ecology are qualitative (as this study is), incomplete or unknown. It seems that this current record of a single mass aggregation of the Port Jackson shark reveals that their behaviour may be even more complex than previously thought.

Acknowledgements

I would like to thank those with whom I have consulted during the preparation of this record, including the late Mike Leigh of Marine Care Ricketts Point, Dr David Powter of the School of Environmental and Life Sciences, Central Coast Campus, University of Newcastle, as well as Dr Barry Bruce of the Division of Marine and Atmospheric Research at the CSIRO in Hobart, Tasmania, and Dr John Stevens (retired, formerly of the CSIRO in Hobart, Tasmania). I would also like to thank the volunteers of Marine Care Point Cooke, and Melbourne Polytechnic.

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Ninety-eight Years Ago

Flying-fishes

By C.L. BARRETT

... From the deck of our boat I have just been watching some flying-fishes, and I thought that a note might be of some interest to members of the F.N.C. Some observers have declared that these fishes vibrate their large pectoral fins when skimming through the air—in fact, that they use them as wings. My observations to-day, and on a previous occasion when I was voyaging in the Pacific Ocean, convince me that the fins are held rigid all the time that the fish is in the air. However, I did see one to-day strike the water with its tail; it did not rise cleanly and rapidly in the first place, and the flip of the tail gave it the necessary impetus for the flight. Another fish I observed made an aerial journey of at least fifty yards. The flying-fishes have been of special interest to me, as we have seen no other form of animal life for some days.

From *The Victorian Naturalist XXXIV*, p. 92, October 1, 1917

Larval Dwarf Green Tree Frogs *Litoria fallax* crushed by trail-bikes

Although mortality to frogs due to crushing by off-road vehicles has been reported from other countries, there are few such reports from Australia. The Dwarf Green Tree Frog *Litoria fallax* (Salientia: Hylidae) is a small arboreal frog widespread in wetlands of the coastal plain and ranges of eastern Australia, south of Cape York Peninsula and north of the border of Victoria (Cogger 2014). There are also extralimital populations of *L. fallax* in and around metropolitan Melbourne, Victoria (Anstis 2013). *Litoria fallax* is frequently locally abundant in swamps and in bulrush (*Typha* spp., Typhaceae) beds, although it has undergone marked decline in recent decades in metropolitan Sydney, New South Wales, mostly due to massive urban residential development and consequent loss of habitat, but also to the practice of local government councils of persistent clearing of *Typha* spp. from streams and water channels (author unpubl. data). This note documents mortality to late larval *L. fallax* due to crushing in their ephemeral pools by illegal trail bike traffic in a reserved area.

Nocturnal wildlife survey was carried out in a 558 ha disturbed remnant dry sclerophyll forest (endangered Cumberland Plain Woodland) with several relatively intact mature patches, on the property of the disused Airservices Australia International Radio Transmitter Station. The property is located between Shanes Park and Wilmot in western metropolitan Sydney. In the course of this survey, observations were recorded in two adjacent drying ephemeral pools. These pools were ~1.5 x 2 m and ~2 x 3 m, both up to ~20 cm depth and formed on a track, at 33.72128°S, 150.79750°E (WGS84 grid), 37 m elevation. Heavy rains over the previous six weeks had formed ephemeral pools in depressions in the unsealed dirt tracks and in low-lying areas, which had been used for reproduction by several species of frog, including *L. fallax*. On 9 March 2012, 11.30 pm (AEST), T_s 21.6°C, 8/8

cc, with occasional drizzle, five larval *L. fallax* nearing metamorphosis (stages 40–42 of Gosner 1960) were found freshly killed, floating on the surface in the pools, with injuries to bodies and tails consistent with crushing. Several fresh tracks from trail bike tyres were noted leading in and out of the pools, which were turbid with suspended silt. Live, apparently uninjured late larval *L. fallax* were also observed in the pools, occasionally breaching the surface for air, but could not be visually censused because of the heavy turbidity. Although public access to the area is nominally restricted and riding of trail bikes prohibited, there is easy ingress at several points, and 2–3 trail bikes were heard active in the area before dusk prior to commencement of survey. Other frogs detected visually via spotlight during survey between 7.00 pm and 11.30 pm were adult *L. fallax*, *L. caerulea*, *L. peronii*, *L. v. verreauxii* (Hylidae), *Limnodynastes peronii*, *L. tasmaniensis* (Limnodynastidae), *Crinia signifera*, and *Uperoleia laevigata* (Myobatrachidae). With the exception of *L. caerulea* all species were heard advertisement calling at various ephemeral pools in the survey area.

Frog mortality has been reported from other geographic regions, due to crushing by the hooves of sheep, e.g. juvenile *Anaxyrus boreas* in Idaho, USA (Bartelt 1998), and cattle, e.g. juvenile and adult *Lithobates luteiventris* in Nevada, USA (Ross *et al.* 1999), and by the wheels of off-road vehicles (COSEWIC 2012; Defenders of Wildlife 2012). However, this appears to be the first Australian report of mortality of late larval frogs due to crushing by the wheels of trail bikes. Trail bike riding in native bushland remnants is a popular recreation for many urban and rural Australians, and frog larvae in small streams and ephemeral pools may be susceptible to crushing by trail bike traffic, including when they are metamorphosing, particularly when ephemeral water bodies start to dry out and riders are more prepared to enter them.

Whilst mortality due to this anthropogenic factor is of low concern for common and widespread species such as *L. fallax*, it would be of high concern for those threatened and vulnerable species with more restricted distributions that breed in ephemeral water bodies. It may require attention and policing by management authorities in National Parks and other reserve areas during the reproductive season.

Acknowledgements

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Visitation by common native birds to eucalypts on Deakin University Burwood Campus, Victoria

The Burwood Campus of Deakin University is located approximately 15 km from Melbourne's Central Business District. The campus has a variety of plants including eucalypts and grevilleas. *Eucalyptus* species include *E. sideroxylon* (Red Ironbark), *Corymbia maculata* (Spotted Gum) and *E. muelleriana* (Yellow Stringy Bark). Many bird species frequent the campus and visit the various plants and I was curious as to whether there would be a difference in the number and types of birds visiting these three eucalypts. I examined three trees of each species at hourly intervals on 5, 6 August 2014, from 8.00 am to 5.00 pm. I focused on four bird species, all native and common: Rainbow Lorikeet *Trichoglossus haematodus*, Noisy Miner *Manorina melanocephala*, Australian Magpie *Cracticus tibicen* and Eastern Rosella *Platycercus eximius*. Each bird belonged to a different foraging guild (Table 1) and I believed that tree visitation would be related to foraging motivation. Both *C. maculata* and *E. sideroxylon* were in flower at the time of my observations.

Over the two days, 54 observations were made for each tree species. The two ground foraging birds, Australian Magpie and Eastern Rosella, were seen only twice in the trees, while 94 Rainbow Lorikeets were seen, most commonly in *C. maculata* (Table 1) and less frequently (but still commonly) in *E. sideroxylon*. Rainbow Lorikeets were not seen to visit *E. muelleriana*. The Noisy Miners, although still common, were less frequent visitors than the Rainbow Lorikeet and were observed in each of the three eucalypt species (Table 1).

The Rainbow Lorikeet is a nectarivore and the Noisy Miner feeds on both nectar and insects, so it was not surprising that these species frequented the flowering trees. *Corymbia maculata* flowers from May to September and *E. sideroxylon* from January to September (Williams and Woinarski 1997). *Eucalyptus muelleriana* flowers from October to February. Lill (2009) found that eucalypt nectar (and/or pollen) formed 86–97% of the diet of urban Rainbow Lorikeets and considered their year-round presence due

Table 1. Bird species observed in three eucalypt species on Deakin Burwood campus

Common name	Scientific name	Guild	Number of birds observed/tree species		
			Eucalyptus muelleriana	Eucalyptus sideroxylon	Corymbia maculata
Rainbow Lorikeet	<i>Trichoglossus haematodus</i>	Nectarivore	0	30	64
Noisy Miner	<i>Manorina melanocephala</i>	Nectarivore/insectivore	6	13	14
Australian Magpie	<i>Cracticus tibicen</i>	Ground insectivore	1	1	0
Eastern Rosella	<i>Platycercus eximius</i>	Ground granivore	0	2	0

to the widespread planting of eucalypts in urban areas. The variety of eucalypts, both native to and not native to Melbourne suburbia and which flower in different seasons, means there is a year-round food source for these birds. Deakin has several more species of eucalypt than the three I examined, including *E. globulus* and *E. leucoxylon*, which are important food sources for Rainbow Lorikeets (Lill 2009).

The Noisy Miners also were significant exploiters of the flowering trees but at 43% and 22% of the lorikeet's usage of *E. sideroxylon* and *C. maculata* respectively. Their visits to *E. muelleriana* were presumed to be motivated by the presence of insect delicacies. Noisy Miners are known to spend 25% of their time foraging on grevilleas when these plants are present (<http://www.birdsinbackyards.net/What-characteristics-urban-gardens-influence-distribution-and-foraging-ecology-Noisy-Miners>: accessed 18 May 2015). Deakin has a variety of Grevilleas in considerable abundance so this may explain why the Noisy Miners were not significant competitors with the Lorikeets.

That each of the two ground foragers visited the eucalypts twice over the two days of my observations shows the importance of these trees as a resource other than for food for birds. Deakin University, Burwood Campus is not an urban park, but the variety of trees provides important resources (e.g. food, shelter, perching

or roosting sites) for these and many other bird species. With urban development continuing to expand into native habitats, it is important to remember to plant large trees to provide for our bird, and other, species. Large trees often are not seen as desirable in the home garden (Kirkpatrick *et al.* 2007), particularly in small to medium sized land blocks. My simple two day study demonstrates that organisations such as universities, which are built on larger land blocks than the average home, are important in providing large trees to suburban regions as resources for wildlife.

Acknowledgements

I would like to thank Dr Maria Gibson for assistance in writing this Naturalist Note and Joe McLean who helped me with my observations.

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A guide to the cockroaches of Australia

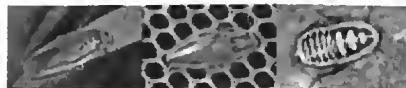
by David C Rentz

Publisher: CSIRO Publishing, Melbourne, 2014.
paperback and ebook, x + 318 pages, ISBN
9780643103207, \$49.95

Let's set the record straight from the outset: I like cockroaches. Perhaps I'm in a minority fortunate to know that cockroaches go way beyond the relatively low number of species that instil fear into suburbanites and could be associated with public health fears. Many naturalists might be familiar with the pest species, but will probably also know the lovely diurnal *Ellipsidion*—such as that in the image which graces the book's cover—and blaberids such as the giant burrowing cockroach (*Macropanesthia rhinoceros*), wood cockroaches (Panesthiinae) encountered in rotting logs, and trilobite cockroaches (*Laxta* species) often abundant under bark of eucalypts and superficially resembling isopods (slaters). Hikers in the southeastern alpine regions may be familiar with the stunning viridescent mountain green cockroaches (*Polyzosteria viridissima* and *P. metallicata*), sunning themselves on vegetation or on the ground during the short mountain summers.

If you have noticed all these and know them, you probably already have a copy of this book. If you haven't noticed native cockroach taxa, then it is time you did, and no excuses—you now have the perfect resource to guide you.

This lovely little book from the CSIRO 'guide to' stable will open your eyes to the wonderful world of cockroach diversity. Here you can delve into the diversity, distribution, and ecology of Australia's 550+ described cockroach species and learn about the estimated 1000+ species remaining to be described! Over 90% of these species are found nowhere else on the planet and many of these Australian species have small ranges ('short' or 'narrow' range endemism), a much more common pattern in invertebrates than in the more frequently studied



A GUIDE TO THE COCKROACHES OF AUSTRALIA



groups of organisms such as vertebrates. Our under-appreciated cockroach fauna deserves the thorough introduction now provided by David Rentz. The guide sets out by introducing the fauna, reminding us that termites are really social cockroaches (though not covered in this book because they are still not cockroaches!) and provides a handy 'how to' guide to approaching cockroach identification.

Before getting to the nitty gritty of reviewing the Australian fauna there are chapters that review key workers in Australian cockroach research, biology, economically important taxa, cockroaches in captivity, collection and preservation, ecology and finally morphology. These chapters provide a context to cockroach research and provide knowledge that will be critical in using the keys and descriptive text to identify cockroaches in the field or 'laboratory'. Although please don't think you'll need to be able to understand and interpret tricky morphological features to gain a great deal from the hook—many species can be identified to genus level by using the illustrations. Two hundred pages introduce the Australian native fauna, abundantly illustrated with colour photographs of, mostly, live specimens, black and white illustrations of critical elements and generalised distribution maps for many taxa. This is where

you can search for your latest cockroach discovery and find out much more about it. What fun!

Well produced, like other similar recent invertebrate guide books by CSIRO Publishing, and copiously illustrated with (mainly) high quality images (more than 500), this book should be on every naturalist's bookshelf or in their day-pack. In an era where many of us consider that Google has the answer to everything, guides of

this nature remind us that it doesn't and that websites rarely, if ever, package information as neatly and conveniently as a well-constructed book.

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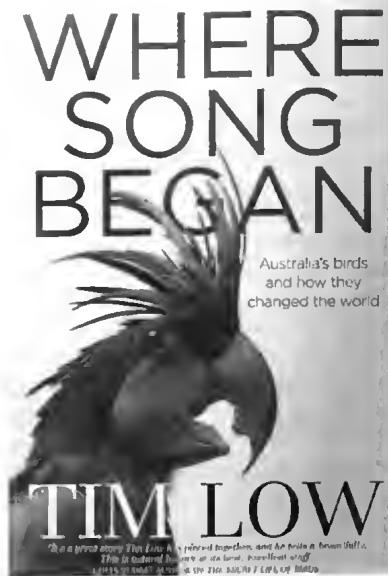
Where song began: Australia's birds and how they changed the world

by Tim Low

Publisher: Viking, Melbourne, 2014. paperback,
406 pages. ISBN 9780670077960. RRP \$32.99

In my small collection of documents about birds there is a snippet from *The Australian*, dated July 24–25 2004, page 24, headed 'Bird theory takes flight'. It refers to a report published in the Proceedings of the National Academy of Sciences, announcing that 'the DNA of ... perching birds ... showed they appeared in the western part of the ancient Gondwana supercontinent, the section which eventually formed Australia, New Zealand and New Guinea'. Thus a 150 year old avian evolutionary theory, which assumed that nightingales, mockingbirds, cardinals, robins and others had evolved in Europe or Asia, was overturned. At the top of the above-mentioned news cutting, a knowledgeable birdwatcher colleague has written 'We knew this ages ago!'

Most people didn't know this ages ago, but thanks to Tim Low's latest skilfully written, very readable book, everyone can become ac-



quainted with the story of how the old theory came to be discarded, and how strongly some eminent biologists rejected the facts. And that's not all — there is a wealth of other information, not only about birds, but also plants, mammals (including people), biogeography, ecology and conservation. The author has travelled extensively to investigate his subject matter, and accounts of his first-hand observations contribute to the book's appeal. Recent research is noted, but this book was published before blame for the spread of the plague through Europe was transferred from the black rat to the gerbil (page 255).

The Introduction (essential reading) precedes twelve chapters, each of which has from four to ten subdivisions, all listed in the Contents along with their page numbers, making for easy navigation. The main text is followed by source notes, a bibliography, acknowledgements, photo credits and a very useful index. There is a sparse sprinkling of typographical errors, but the only one that bothered me is on page 36, where the Striated Pardalotes in the photo are referred to as 'striated honeyeaters'.

The book begins with a fascinating section about sugar. In forms such as nectar, lerp, plant exudates and manna, this substance has led to aggressive avian defence of food sources and, in many cases, harsh calls to match. However, as the chapter titled 'The First Song' indicates, Australia also has some fine songsters, especially the lyrebirds which, along with the scrub-birds, are of ancient origin. Songbirds have influenced human music, a fact that prompts Low to ask 'whether human music would have reached the height it has had that first songbird not sung in an Australian rainforest' (page 77).

Other topics explored include relationships between Australian birds and those of New Guinea; Australia as a land of parrots (termites and fires have a role here); the Southern Cas-

sowary; birds creating habitats by spreading seed; ocean birds; and people's treatment of birds. Much of the latter is shocking, for example the slaughter of millions of birds; the thoughtless, disastrous destruction of habitats; inappropriate feeding; and widespread disrespect for the domestic chicken. Some species have taken advantage of the effects of human presence, but sadly many others — especially small birds — are present in far fewer numbers than they used to be. Governments have found that they can cut funding for the protection of threatened species without losing elections, and with plenty of noisy, smart, colourful members of the parrot family in full view, it is easy for other species to be forgotten. Low points out that any discussion about declining birds must include the winners people see, or it will fall on deaf ears.

I found this book quite gripping, and am not surprised that it has met with an enthusiastic reception. If you haven't read it yet, make sure you don't miss out.

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Ninety-nine Years Ago

Bird life on Fraser Island, Gippsland Lakes

By G.A. KEARTLAND

For many years the scarcity of native birds in the vicinity of any of the larger towns has been very noticeable, and what few are seen are so wild that nature-students seldom obtain a close view of them without recourse to the gun. Even with that aid many are too shy to be approached within killing range. Various opinions have been expressed as to the cause of this state of affairs. Whilst some attribute it to the introduction of starlings, minahs [sic], and sparrows, which are now to be found in thousands in some of the parks or on farms near Melbourne, others are equally certain that what have not been killed or driven away by thoughtless shooting have fallen victims to the domestic cat. Perhaps both views are to some extent right.

From *The Victorian Naturalist XXXIII*, p. 42, July 6, 1916

